

On behalf of:



Federal Ministry  
for the Environment, Nature Conservation  
and Nuclear Safety

of the Federal Republic of Germany



**giz** Deutsche Gesellschaft  
für Internationale  
Zusammenarbeit (GIZ) GmbH



## **Solar Cooling for Industry and Commerce Experiences gained in Jordan**

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**GIZ, Proklima**

**World Bank's International Conference on Sustainable Cooling  
Washington DC, Nov 28-30, 2018**



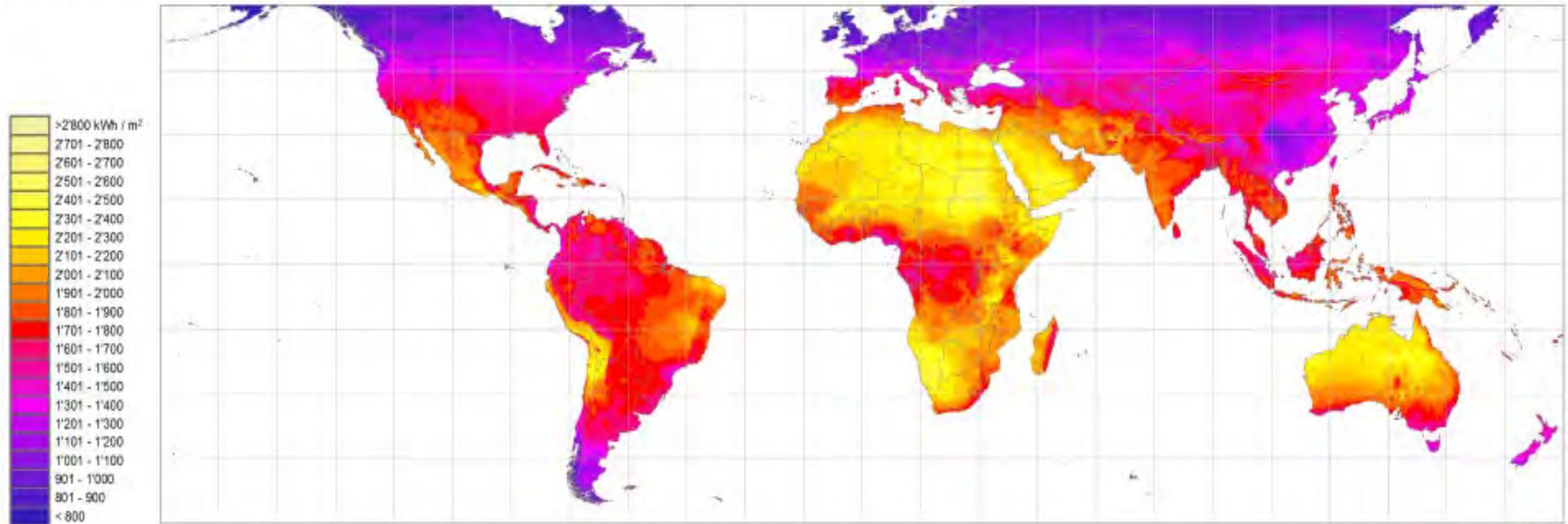
# Agenda

- Introduction to solar cooling and Jordan conditions
- Industrial & commercial solar cooling in Jordan
- Economic Feasibility - Costs
- Gained Experiences
- Recommendations
- Up-scaling



# Global Solar Irradiation

Yearly sum of Global Horizontal Irradiation (GHI)



Source: Meteonorm 7.1 ([www.meteonorm.com](http://www.meteonorm.com)); uncertainty 8%  
Period: 1991 - 2010; grid cell size: 0.125°

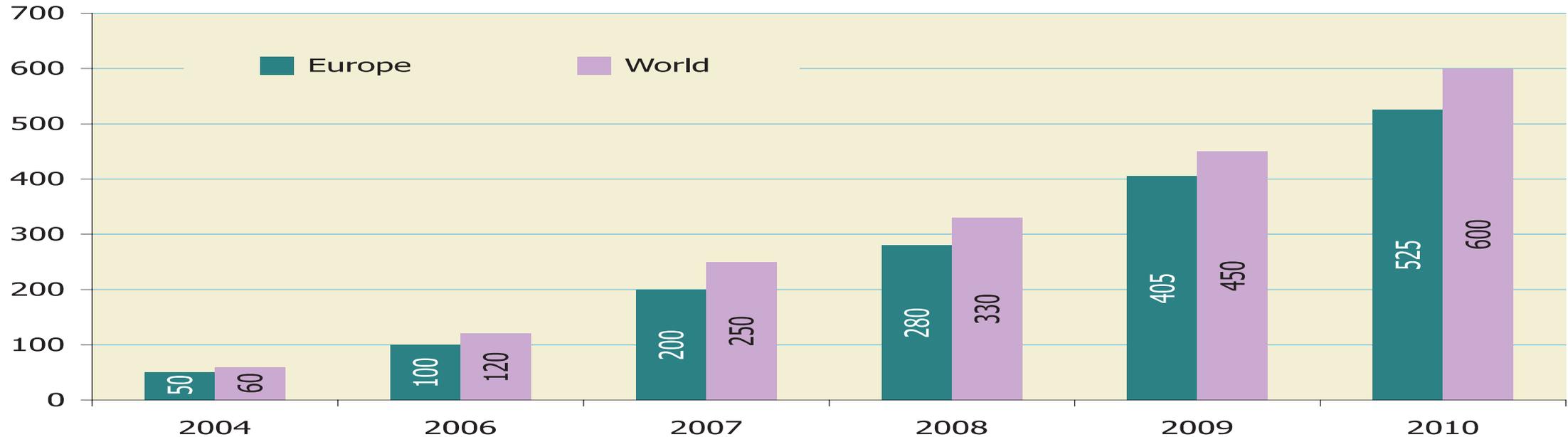
March 2014





# Increasing number of solar cooling systems installed globally

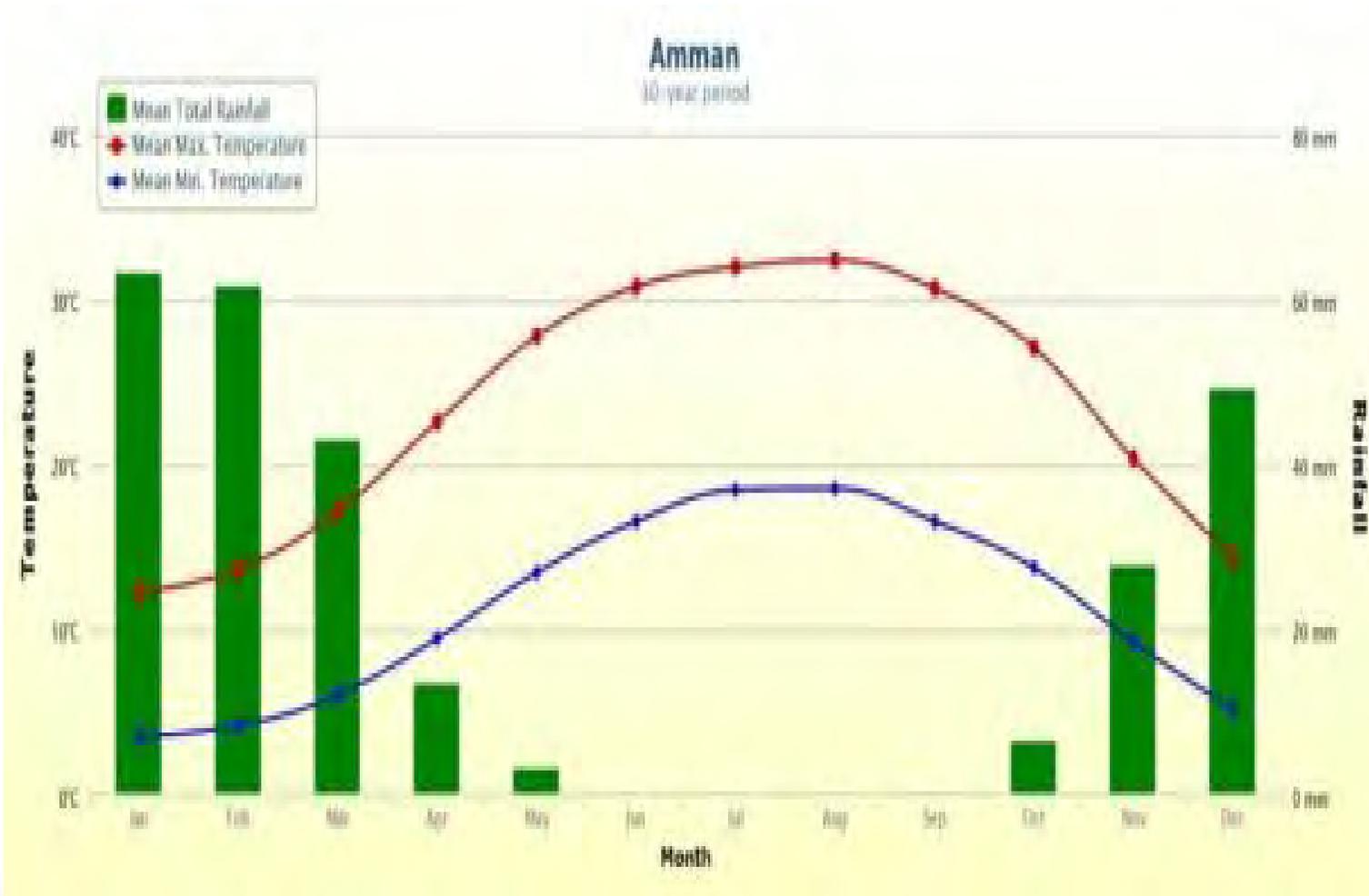
Total amount of installed solar cooling systems in Europe and the world



- In 2015 around 1350 solar thermal cooling systems had been installed globally.
- Market is growing as costs come down. (IEA, 2018)



# Climate and ambient temperature in Jordan

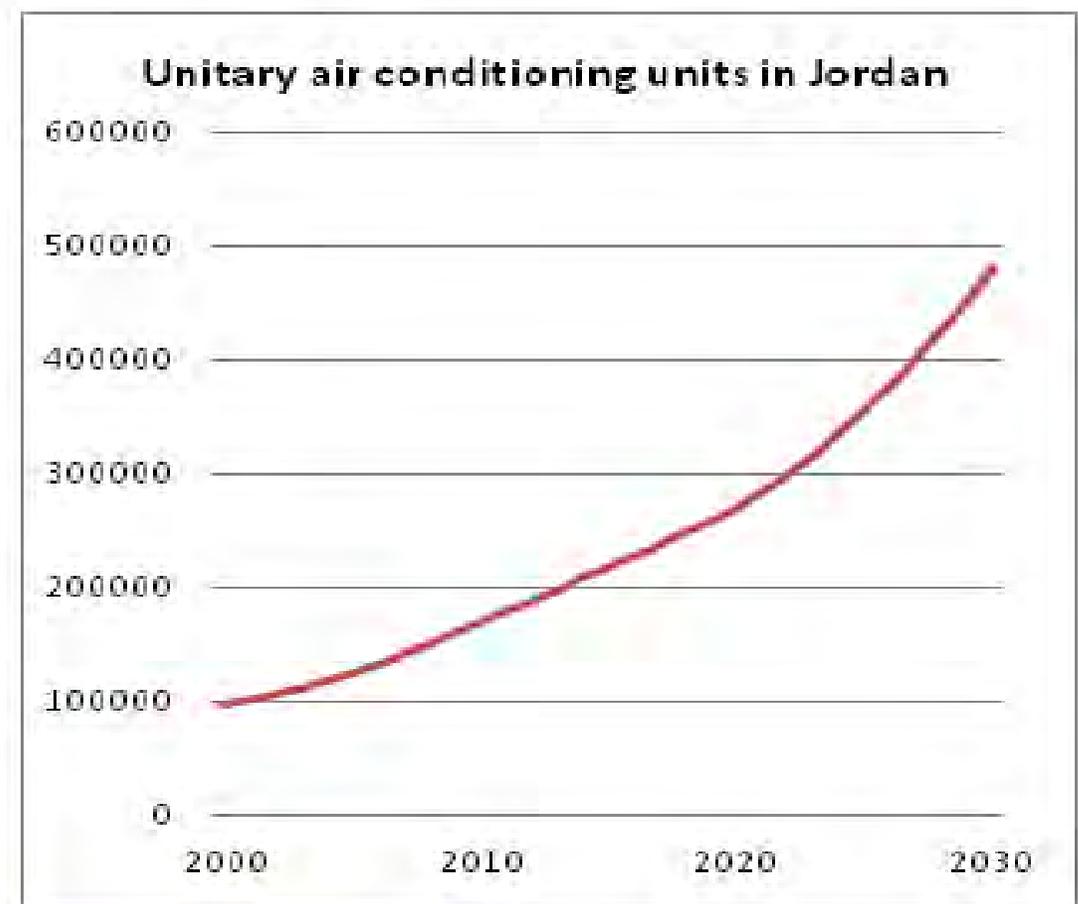
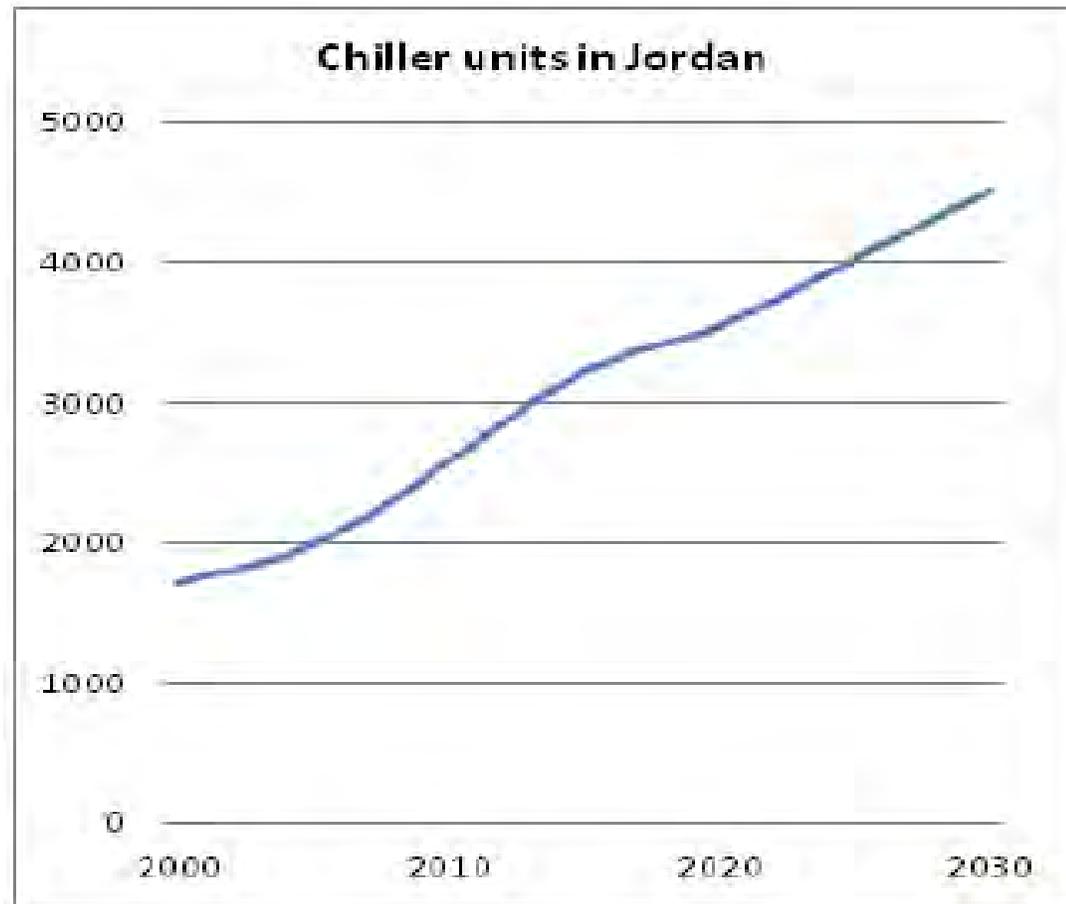


Extreme heat and dry climate  
(Apr.-Oct.)

## Excellent Conditions:

- High solar radiation
- Small proportion of indirect radiation
- High cooling demand and high solar irradiation are overlapping

# Estimated Future Demand of AC in Jordan

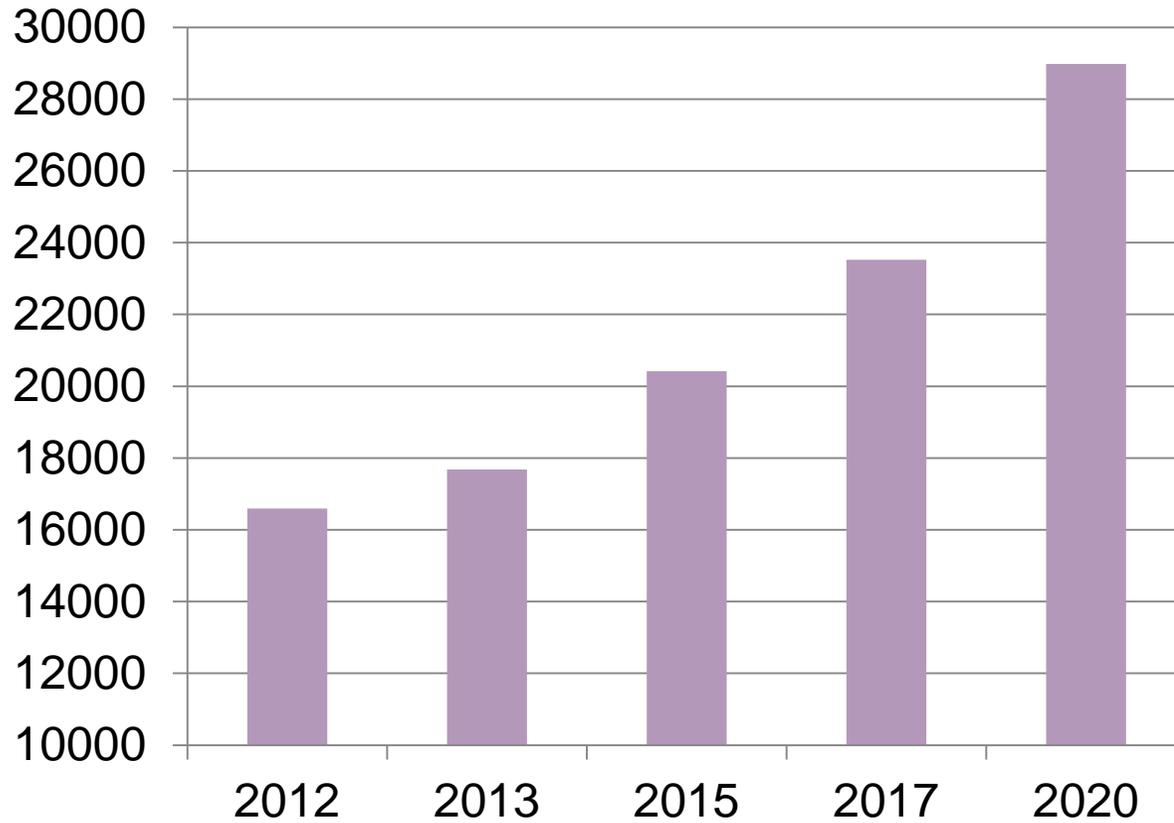


Stock of chiller and unitary air conditioning units in Jordan:

Source: Green Cooling Initiative (GCI), <http://www.green-cooling-initiative.org>



## Electrical Energy Demand Forecast in Jordan (GWh)



Quelle: Energy 2013 - Facts & Figures, Ministry of Energy and Mineral Resources, Jordan

## Electricity prices rise 15% per year

التعرفة الكهربائية للفترة من 2013-2017

التعرفة الكهربائية لعام 2017	التعرفة الكهربائية لعام 2016	التعرفة الكهربائية لعام 2015	التعرفة الكهربائية لعام 2014	التعرفة الكهربائية اعتباراً من 2013/8/15 وحتى 2013/12/31	القطر
183	159	138	120	105	د. المشتركين التجاريين
255	222	193	168	146	من 1- 2000 كيلو واط ساعة شهرياً أكثر من 2000 كيلو واط ساعة شهرياً
3.79	3.79	3.79	3.79	3.79	ح- تعرفه المشتركين الصناعيين المتوسطين
127	110	96	83	72	1- الحمل الأقصى (دينار/ك.و/شهر)
107	93	81	70	61	2- التزويد النهاري 3- التزويد الليلي

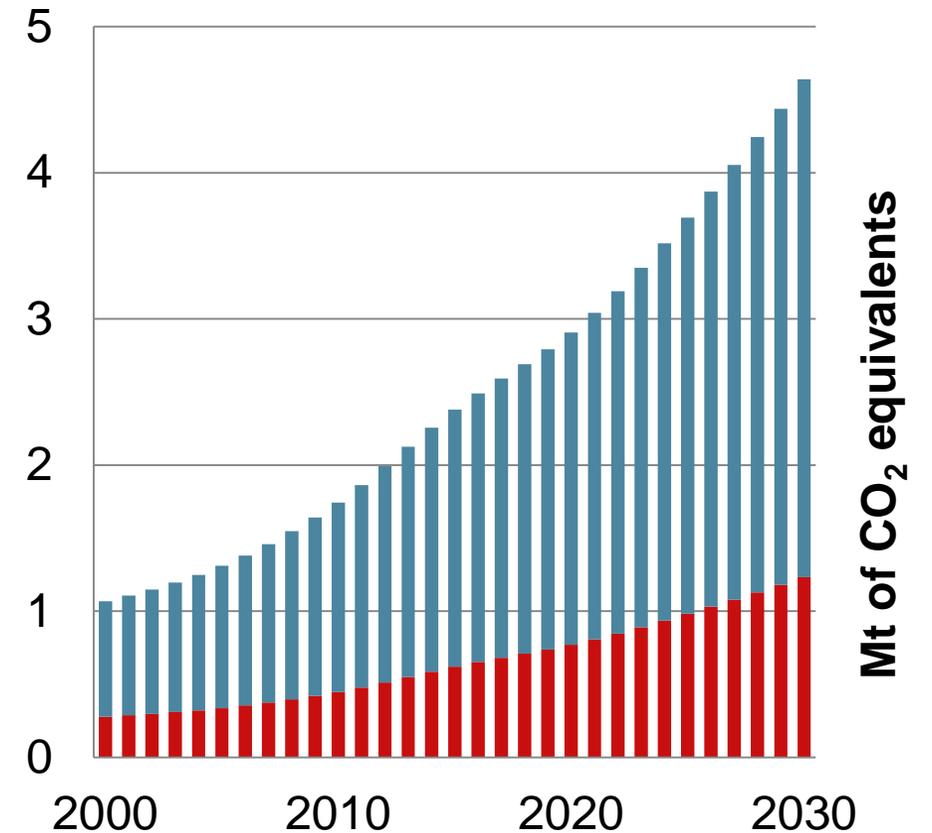
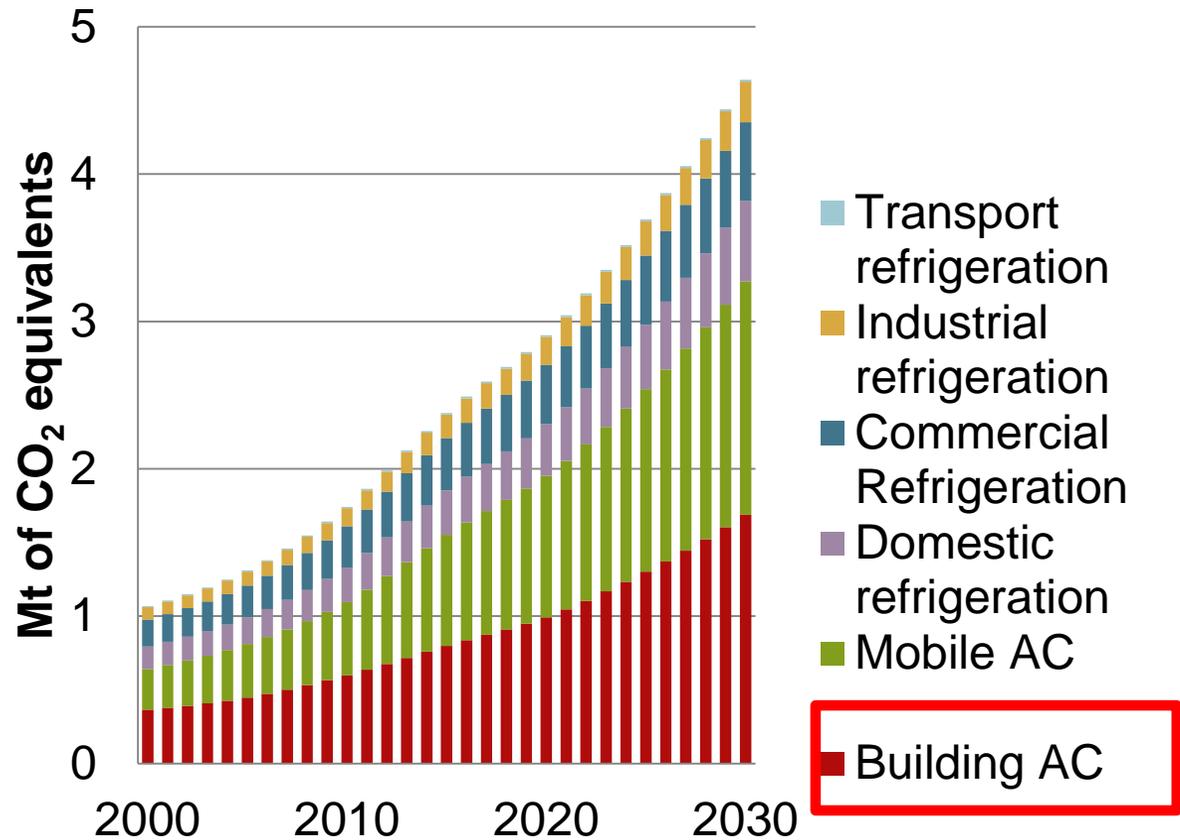
75% price increase in 4 years

Source: Electricity Regulatory Commission, Jordan

مصدر: هيئة تنظيم قطاع الكهرباء, الأردن



## Emissions caused by RAC in Jordan by sectors



Own estimations based on

Green Cooling Initiative Methodology <http://www.green-cooling-initiative.org/methodology/>

NAMAs in the refrigeration, air conditioning and foam sectors, *A technical handbook by GIZ Proklima*

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## Solar Cooling for Industry and Commerce, Jordan

**Budget:** 3.2 Million EUR (German Ministry of Environment)

**Objective:** Demonstrate feasibility and suitability of solar power cooling in Jordan and the region

- Technology cooperation and transfer
- Local knowledge established for replication
- 4 lighthouse projects up and running

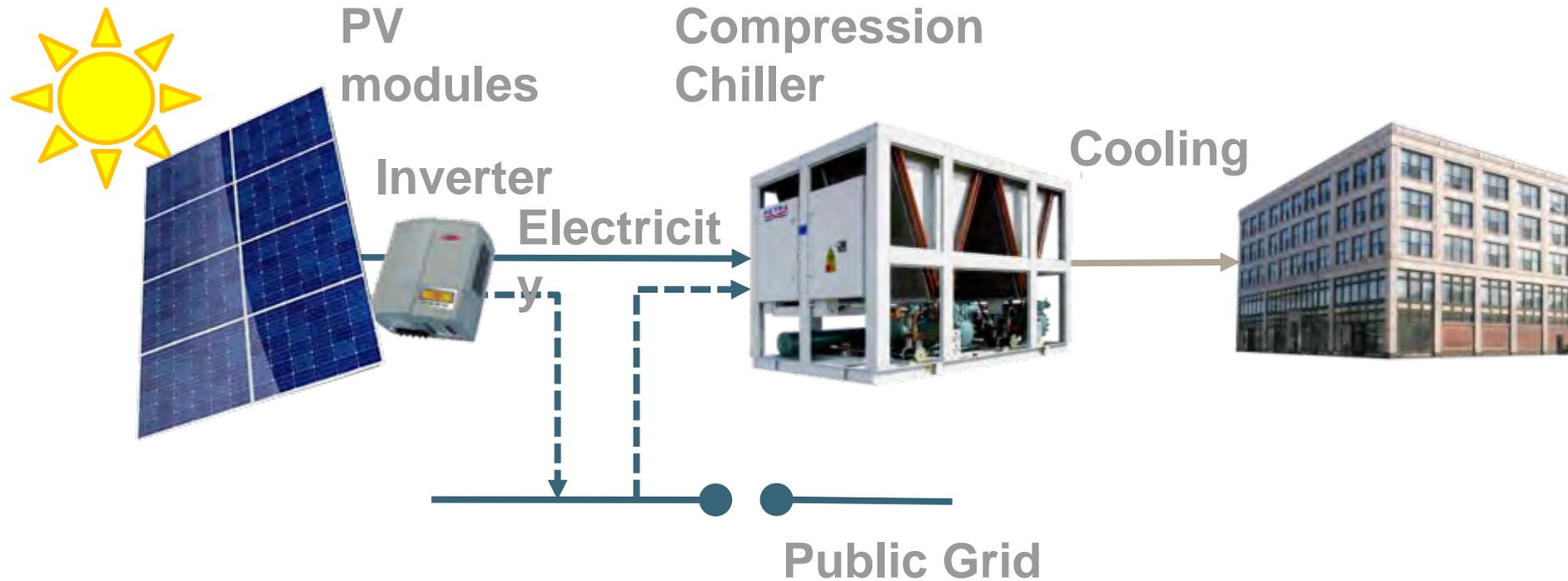
**Project Partners:** Jordan Ministry of Environment, GIZ, Technical University of Berlin, Jordan Manufacturer, Jordanian Universities and Research Institutes

In cooperation with:



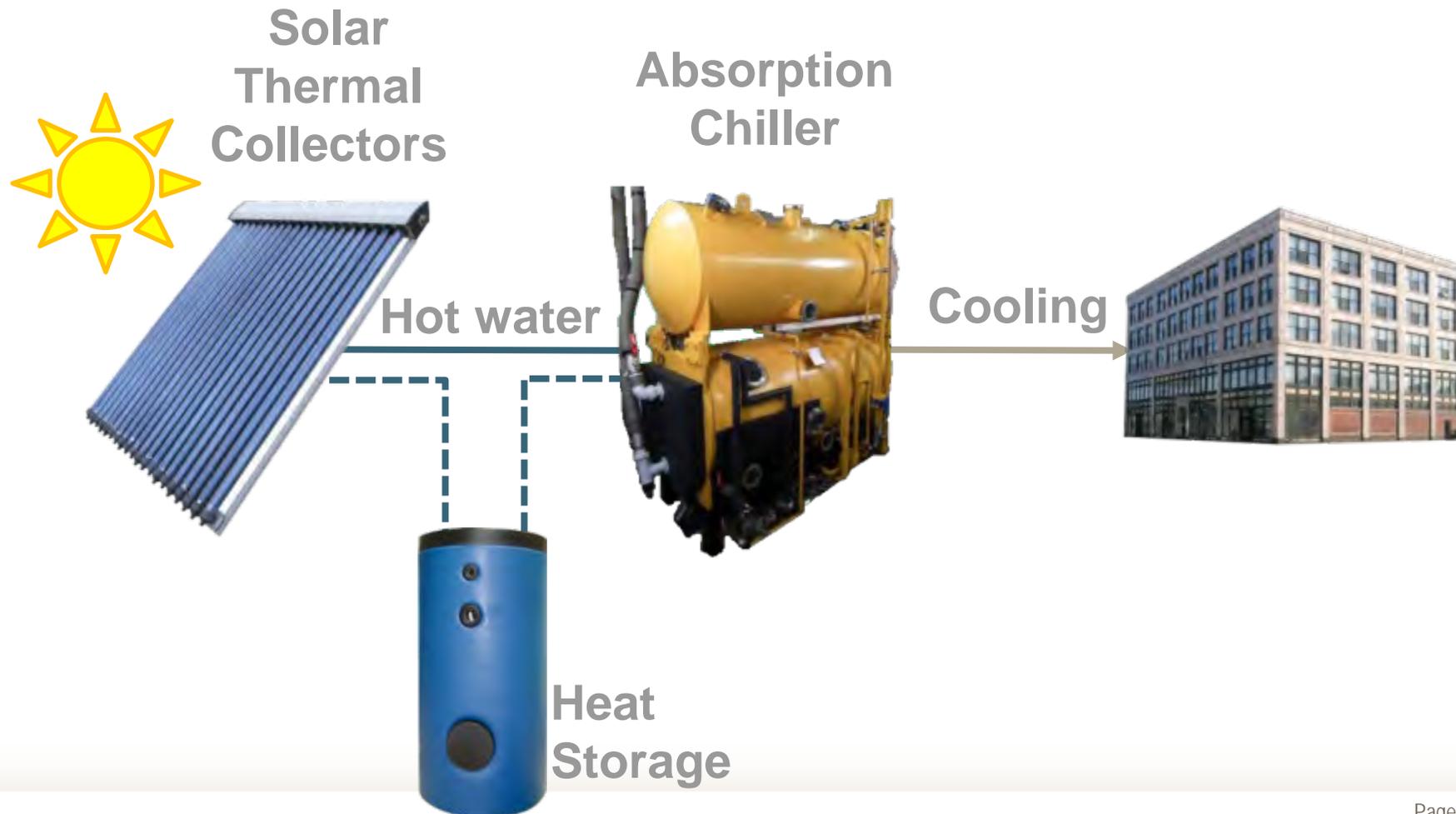


## Compression Chiller combined with PV



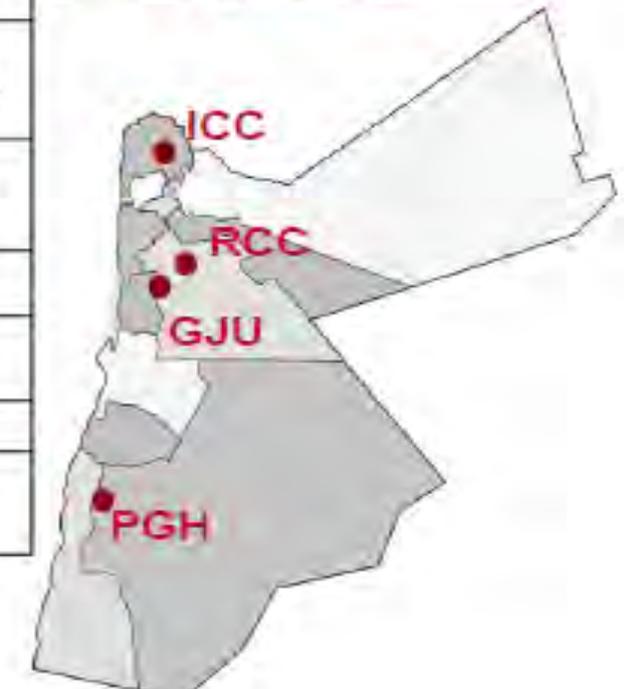


## Absorption Chiller with Thermal



# Solar Cooling Systems in Jordan

	<b>German Jordan University (GJU)</b> 	<b>Petra Guest House (PGH)</b> 	<b>Royal Culture Center (RCC)</b> 	<b>Irbid Chamber of Commerce (ICC)</b> 
<b>solar system</b>	solar heat for heating- & DHW / AbC Compound Parabolic Collectors (CPC)			
	150 CPC, 480m <sup>2</sup> <sub>gross</sub>	114 CPC, 388m <sup>2</sup> <sub>gross</sub>	132 CPC, 449m <sup>2</sup> <sub>gross</sub>	41 CPC, 140m <sup>2</sup> <sub>gross</sub>
<b>heat storage</b>	4 x 3,5m <sup>3</sup> for heating <i>hydraulically decoupled</i>	4 x 3m <sup>3</sup> for heating/cooling <i>hydraulically coupled</i>	3 x 3m <sup>3</sup> for heating <i>hydraulically coupled</i>	1 x 3m <sup>3</sup> for heating <i>hydraulically coupled</i>
<b>chiller(s)</b>	TUB absorption chiller - type bumblebee (FM160V021)			TUB AbC type Bee (FM050V021)
	1 / 2 direct air cooled compression chillers			
<b>reject heat device</b>	dry cooler - GEA V-Bank type			
<b>cooling load</b>	operating temperatures 8,7 - 9°C to 14°C			
	8 to 16	24h/7d design: 8-12 am + 6-12pm	8-24	8-16



**AKA Typ bumblebee (160kW)**

**Bee (50kW)**

# Solar Cooling Systems in Jordan

## German Jordan University (Pilot 1)



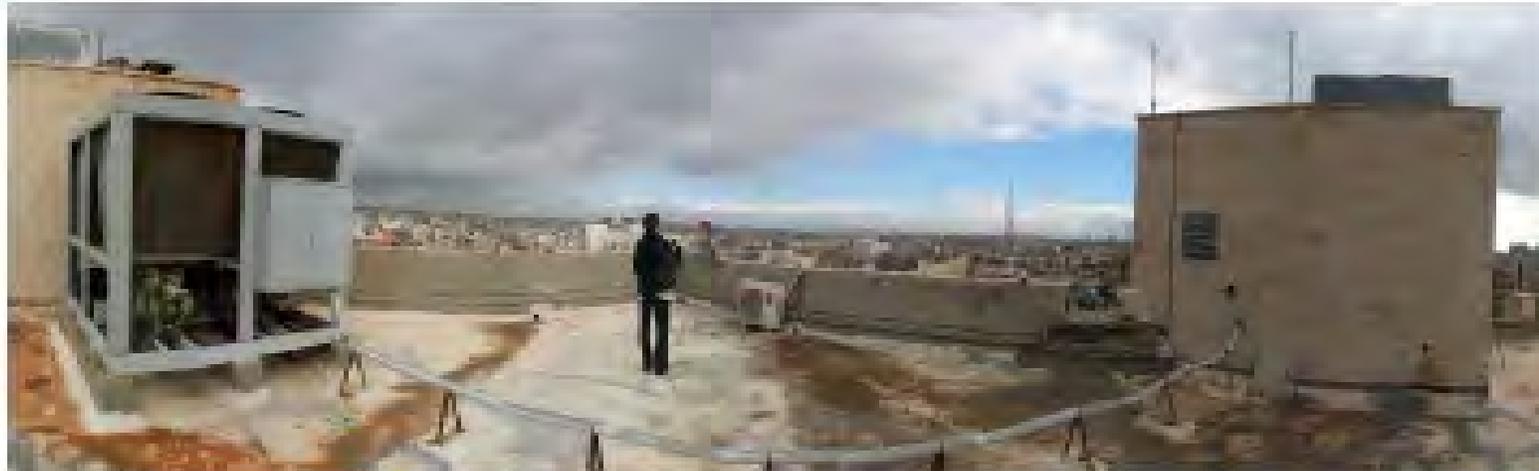
# Solar Cooling Systems in Jordan

## Petra Guest House (Pilot 2)



# Solar Cooling Systems in Jordan

## Irbid Chamber of Commerce (Pilot 3)



# Solar Cooling Systems in Jordan

## Royal Cultural Center Amman (Pilot 4)





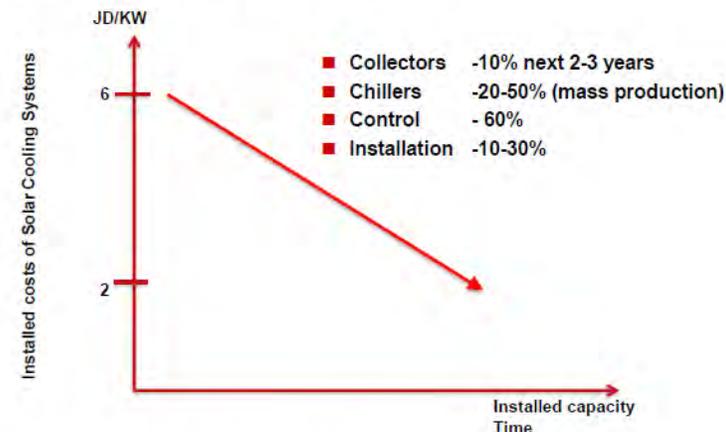
## Economic Feasibility - Costs

- Solar field highest cost factor
- Investment costs of solar thermal cooling between 1,600 and 3,200 USD per kW of installed cooling power (IEA 2012); [3,300 € per kW of cooling]
- Operational costs are considerably lower
- Payback: depends on local conditions; electricity prices, availability of components, incentive scheme, etc.

### Component typical share of total costs:

<b>Chiller</b>	<b>18%</b>
<b>Control</b>	<b>8%</b>
<b>Auxiliaries</b>	<b>14%</b>
<b>Solar Collector</b>	<b>42%</b>
<b>Heat rejection</b>	<b>8%</b>
<b>Design &amp; Planning app.</b>	<b>10%</b>

### Decreasing cost trends



Source: IEA, SHC, Mugnier, Tecsol, 2010

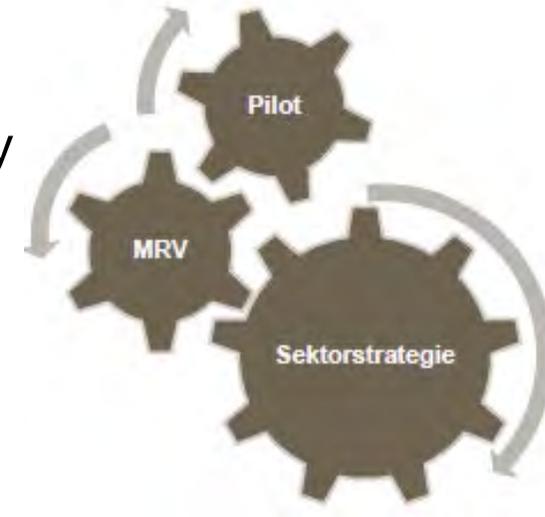
## Gained Experiences



- 4 solar demo projects show excellent results
- 30% higher efficiency compared to conventional systems
- Lower operation and maintenance costs
- Local business partner on the ground to ensure sustainability
- Pilot – MRV – Sector Strategy for Jordan

## Recommendations

- Small roof area exposed to solar irradiation
  - PV-supported Hydrocarbon Compression Chiller
- Large roof area exposed to solar irradiation
  - Absorption Chiller with Solar Thermal collectors
- Roof with high amount of shading
  - Conventional Hydrocarbon Compression Chiller





## Up-scaling is needed

- About every second commercial building in Jordan uses a chiller system and around 5% (150 units) are broken and exchanged every year - rising numbers
- Solar/geothermal hybrid cooling systems in Oman is implemented
- Higher capacities are required - development of 500kw solar absorption chillers
- Although costs are decreasing - further projects are required to decrease technology costs
- Package products are needed
- Local production of the technology might be an option in the future



# Thank you for your attention!

Contact:

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Proklima International

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